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1.0 Introduction

1.1 Purpose and Proposed Action

The purpose of this Environmental Assessment (EA) is to support the program continuation decision and proposed action to initiate the design/demonstration phase (Phase II) of an Advanced Technology Demonstrator Vehicle, Experimental-Thirty Three (X-33) as part of the National Aeronautics and Space Administration's (NASA) Reusable Launch Vehicle (RLV) Technology Program. This program will implement the National Space Transportation Policy, specifically Section III, paragraph 2(a): "The objective of NASA's technology development and demonstration effort is to support Government and private sector decisions by the end of this decade on development of an operational next-generation reusable launch system." Phase II would consist of final design, fabrication, assembly, and test of the X-33 spaceplane. The X-33 spaceplane will be flight tested using an expansion of the flight envelope (maximum speeds necessary to demonstrate the technique required for orbital capability around the Earth) to demonstrate "aircraft like" operations. Technical, logistics, operations, and business plans proposed by offerors in response to NASA's Cooperative Agreement Notice (CAN) 8-3, "X-33 Phase II: Design and Demonstration," issued April 1996 (MSFC 1996) will be used by NASA to select an Industry Partner to proceed with NASA to implement Phase II.

1.2 Background

1.2.1 RLV Program

For many years, the United States (U.S.) has recognized that space transportation costs must be significantly reduced so that the Nation can afford to continue to expand its exploration, development, and use of space. In NASA's *Access to Space Advanced Technology Team Final Report,* a single-stage-to-orbit (SSTO) transportation architecture was recommended as a prime candidate for the next generation of reusable space transportation systems which could meet future requirements with significant reductions in annual operating costs (NASA 1993). On August 5, 1994, President Clinton's Space Transportation Policy assigned NASA as the lead Agency for advanced technology development and demonstration for the next generation of reusable launch systems. Work involved to support this effort would focus on the Advanced Technology Demonstrator Vehicle X-33.

Proposed implementation of the X-33 Program has been divided into three phases. Phase I, which was the purpose of CAN 8-1 (MSFC 1995-A), required 15 months to accomplish preparation of concept definition and preliminary design of the reusable advanced technology demonstrator system, X-33. The X-33 includes the flight spaceplane, supporting ground based technology demonstrations, and any required ground and flight support systems. Based on results of Phase I and evaluation of proposals received in response to CAN 8-3, an Industry Partner will be selected for Phase II, if a decision is made to continue the program.

In March 1995, NASA signed three Cooperative Agreements for Phase I. The X-33 Cooperative Agreements were signed with Lockheed-Martin Skunk Works, Palmdale, California; McDonnell-Douglas Aerospace, Huntington Beach, California; and Rockwell International Corporation, Space

Systems Division, Downey, California. The Office of Space Access and Technology at NASA Headquarters in Washington, DC, manages the RLV Technology Program. Marshall Space Flight Center (MSFC), Huntsville, Alabama, is host center for the X-33 Program. The U.S. Air Force (USAF) supports NASA in management of test flight and operations. Also, various Government laboratories would participate with industry members to apply the technology developed toward this next-generation launch system. The following Government laboratories have been identified, to date, with existing expertise to be of assistance in expediting the success of this program: MSFC in Huntsville, Alabama; Ames Research Center (ARC) in Santa Clara County, California; Lewis Research Center (LeRC) in Cleveland, Ohio; Langley Research Center (LaRC) in Hampton, Virginia; Johnson Space Center (JSC) in Houston, Texas; Jet Propulsion Laboratory (JPL) in Pasadena, California; Kennedy Space Center (KSC) in Brevard County, Florida; Stennis Space Center (SCC) in Hancock County, Mississippi; USAF Phillips Laboratory (PL) on Edwards Air Force Base (EAFB) near Lancaster, California; and USAF Wright Laboratories in Cleveland, Ohio. Other Government centers are contributing to the program as well.

Enabling an SSTO system is the ultimate goal of the RLV Technology Program. An SSTO system would operate in an "aircraft-like" mode; (i.e., the entire spaceplane with all fuel tanks and engines are launched and returned to earth in one unit, unlike the Space Shuttle which ejects the external tank (ET) and two reusable boosters during ascent). No stages will be dropped with an SSTO system. To meet the technical and programmatic challenges of development of a fully reusable SSTO vehicle, key advanced technologies in reusable systems must be explored. Therefore, specific goals of Phase II of the RLV Technology Program are to demonstrate improved operability, safe abort, reusability, and affordability through ground and flight tests. If Phase II is fully successful, it will enable a low-risk, low-cost development of a commercially operated RLV system or spaceplane. Advanced technologies would also be used to enhance operation and performance of existing space vehicle fleet(s), where possible. Specifically, the experimental flight portion of the program would be used to verify full-scale system operability in "real world" environments.

As part of the integrated planning for this new program and in consideration of NASA's environmental responsibility under the National Environmental Policy Act (NEPA), this programmatic EA has been prepared for the activities required to support the X-33 Program. Program elements are described in NASA's CAN 8-3, issued April 1996, and significant portions of the following text are taken directly from this program document (MSFC 1996).

The X-33 will demonstrate critical technologies needed for orbital SSTO vehicles in realistic operational environments. To the extent practical, the X-33 will be tested in ascent and reentry flight environments of a full-scale SSTO vehicle. In addition, X-33 will focus on those operational issues which are critical to development of reliable, low-cost, reusable space transportation. The X-33 will incorporate more advanced materials with weights and margins equivalent to those required by an SSTO vehicle. The X-33 supportability goals are key to lower cost system operations. The operability and performance demonstrated by the X-33 will provide necessary data to establish detailed requirements for a future operational SSTO vehicles. The X-33 Program has an unprecedented opportunity to systematically flight test a realistic, full-component prototype spaceplane in a stepwise manner. Initial flight tests would be conducted entirely within Government-controlled test ranges to ensure reliability, reusability and performance prior to long-range flights (up to approximately 1900 km (1200 mi)) at high speeds approaching Mach 15 (15 times the speed of sound or 18,000 km/hr (11,000 mph)).

Phase II will consist of final design, fabrication, assembly, and test of the X-33 spaceplane. The X-33 spaceplane will be flight tested using an envelope expansion flight program to demonstrate aircraft-like operations. Flight testing will be accomplished using an appropriate test range for primary operations, including takeoff and initial on-range flight tests, and return site for checkout and reflight. It is anticipated that Phase II will be completed by the year 2000. Phase II will also develop all necessary data to support an informed program continuation decision at the completion of the phase. Data will include program planning and a detailed business plan for Phase III and an operational RLV system designed to a level sufficient to provide a high confidence cost estimate and show that all program risks have been identified and are acceptable.

Phase II is focused towards demonstrating technology to build RLV's with aircraft-like operations. Phase III will include design, manufacture, and operation of the RLV system. Execution of Phase III is an industry decision. In Phase III, the Government would become a customer, not an owner or operator, of the launch system(s).

A companion RLV program focused on a test vehicle exploring aircraft-like operations named the DC-X for Delta Clipper-Experimental which was also an unpiloted, single-stage vehicle. Its purpose was to provide early demonstration of new technologies needed for a reliable, affordable RLV that could be operated commercially by American industry with NASA as one of its customers. Validation with static test firings at the U.S. Army's White Sands Missile Range (WSMR), New Mexico; NASA's White Sands Test Facility (WSTF), a tenant on WSMR; and launch and flight test activities at the White Sands Space Harbor (WSSH) on WSMR were successfully conducted by the Ballistic Missile Defense Organization (BMDO) (formerly Strategic Defense Initiative Organization (SDIO)) and the Air Force Phillips Laboratory. No significant environmental impacts were expected as a result of the EA prepared by SDIO (SDIO 1992).

The follow-on program to the DC-X is the responsibility of NASA and has been named the DC-XA for Delta Clipper - Experimental Advanced. On June 7, 1996, the DC-XA was renamed the "Clipper Graham" in honor of the late Lt. General Daniel O. Graham, the original proponent of SSTO vehicles. Specific test objectives of the Clipper Graham flight series tests are forerunners and complementary to those of the X-33 and include:

- verify functional integrity and operational suitability of a:
  - composite liquid hydrogen (LH_2) tank
  - composite intertank
  - aluminum-lithium (Al-Li) liquid oxygen (LOX) tank
  - auxiliary propulsion system under typical flight conditions;
- verify functional compatibility of Clipper Graham vehicle, flight operations control center, and ground support services under launch and flight conditions;

- verify key operability and supportability features of hardware and software under launch and flight conditions; and

- determine operational characteristics and flight readiness of the Clipper Graham vehicle.

A series of flight tests with an approximate maximum range of 3 km (1.8 mi) will be conducted at WSMR during the summer of 1996 to validate important new technologies and enhance the reliability and success of other RLV programs such as the X-33. Data from the Clipper Graham program will be universally available to any successful competitor continuing to work on Phase II of the X-33 Program. Environmental considerations for the Clipper Graham were essentially the same as those previously documented for the DC-X Test Program, and the DC-X EA results were readopted for the DC-XA, now Clippper Graham (MSFC 1995-C).

1.2.2 X-Plane Program

The U.S. X-Plane Program has evolved from being the first rocket-powered airplane to break the sound barrier (the X-1 on October 14, 1947) and included over 30 different major research designs, although not all were developed into flying prototypes (Hallion 1984, Miller 1988, DFRC/EAFB 1994-A/B, DFRC/EAFB 1995). As the program progressed, other non-rocket-powered experimental aircraft were built and tested. These aircraft included: a range of vertical takeoff and horizontal landing (VTHL) vehicles; smaller, propeller-driven reconnaissance vehicles; and a series of unmanned missile testbeds of both single and multistage designs. Although the program grew to include conventional propeller-driven aircraft, all designs had in common the aspect of being highly valuable research tools for advancement of aerodynamics and astronautics.

Accomplishments of the X-Plane family have been many. The program included: (1) the first aircraft to break the sound barrier; (2) the first aircraft to use a variable-sweep-wing in flight; (3) the first to fly at altitudes in excess of 30,000, 60,000, and 90,000 m (100,000, 200,000 and 300,000 ft); (4) the first to use exotic alloy metals for primary structure; (5) the first to test gimbaled jet and rocket engines; (6) the first to use jet-thrust for launch and landing; (7) the first to fly three, four, five, and six times the speed of sound; (8) the first to test boundary-layer-airflow control theories over an entire wing at transonic speeds; (9) the first to successfully complete a 180 degree turn using a post-stall maneuver; and (10) the first missile to reach an intercontinental flight range.

The majority of testing for the X-Plane family has occurred at EAFB (formerly known as Muroc Army Air Field). Hosts within EAFB include the Air Force Flight Test Center (AFFTC) and Dryden Flight Research Center (DFRC). Other sites which have served as X-Plane testing sites include: LaRC and ARC; various Government-owned ships; WSMR, New Mexico; Wright-Patterson AFB, Ohio; Cape Canaveral Air Station (CCAS), Florida; Pinecastle AFB, Florida; Buffalo, New York; and the National Aviation Facilities Experimental Center in Atlantic City, New Jersey. EAFB has seen more X-Plane programs and test flights than any other similar facility in the U.S.

As with every research program testing prototype equipment, the X-Plane Program has not been without technical glitches and equipment failures. Since the beginning of the program's manned flight operations in 1946, approximately 15 major accidents and 4 fatalities (pilots) have been associated with manned vehicle tests. Three of these fatalities were from the X-2 Program, flown between 1952 and 1956, and the remaining fatality happened in 1967 during an X-15 research flight. Stringent range safety controls have resulted in no civilian property damage losses or fatalities being reported as a result of any X-Plane Program accident. Given the overwhelming number of test flights, the small number of accidents which resulted in loss of aircraft or life can be considered a remarkable program achievement. Table A-1 in Appendix A provides key information about each plane tested in the X-Plane series of vehicles.

Another member of the X-Plane Program would be the X-33. As a reusable spaceplane, the X-33 continues the research line developed by various components of the X-Program, such as the X-10 which tested cruise missile components; the X-12, the Atlas B missile which tested one-and-one-half propulsion staging and obtained the first intercontinental flight distance for a U.S. missile; the X-15 which explored the problems of space and reentry at high speeds (Mach 6) and altitudes; the X-17 which explored high Mach effects on reentry vehicles; and the X-23A which was the first maneuvering lifting reentry vehicle. The X-17 was a multistage rocket design which transported various reentry vehicle configurations to very high altitudes to examine their reentry characteristics. The X-23A was launched by a modified intercontinental ballistic missile (ICBM) and utilized a "lifting body" design to glide back to earth. Information acquired from the X-23A was instrumental in later development of the Space Shuttle.

1.3 Need and Scope

This EA was prepared in accordance with the requirements of NASA Handbook (NHB) 8800.11, "Implementing the Provisions of the National Environmental Policy Act (NEPA)." NASA intends that the EA be part of the overall evaluation process, selection of an Industry Partner, and preparation of a Cooperative Agreement to accomplish the X-33 Phase II: Design and Demonstration Program. The EA addresses potential alternative spaceplane concepts, propulsion systems, and primary (primary takeoff and operations) sites. Alternate site(s) with intervening off-site test flight corridors are described generically, and preliminary environmental evaluations and issues are noted. Following Industry Partner selection, if the decision is made to continue, the program will become fully defined and preference and alternative corridors will be evaluated in comprehensive detail in a second environmental document. No new manufacturing facilities are contemplated by NASA at this time. Therefore, none will be addressed in this EA.

2.0 Description of Proposed Action and Alternatives

2.1 Proposed Action

The proposed action for analysis in this EA is the decision to implement Phase II of the X-33 RLV Advanced Technology Demonstrator Program. The planned program will combine ground and flight demonstrations. The X-33 concept involves a remotely piloted, subscale spaceplane, approximately one-half the size of a full scale SSTO capable of carrying payloads and crew into orbit. Technology demonstration flight tests are a key part of Phase II. Recommendations for primary locations for these activities have been provided to NASA from the three Phase I Industry Partners. From the recommendations, data and concepts developed during Phase I, program alternatives have been considered in the following areas: spaceplane concepts; propulsion systems and primary flight test operations facilities (facilities for spaceplane assembly, verification, data acquisition and analysis, initial takeoff and on-range flight testing, and primary site for spaceplane takeoff into off-site test flight corridors). Alternate flight test operations (landing and return sites for flight testing with minimal operational support capability) and test flight corridors will be evaluated generically to identify and scope the magnitude of relevant environmental issues.

2.1.1 Specific Technical Objectives

Specific technical objectives to be met in Phase II are to:

- conduct flight and ground tests necessary to reduce business and technical risks which are currently barriers to privately financed development and operation of a next generation space transportation system;

- design and test the X-33 spaceplane, subsystems, and major components and ensure traceability (technology and general design similarity) and scaleability (directly scaleable weights, margins, loads, design, fabrication methods, and testing approaches) to a full scale SSTO system;

- demonstrate key "aircraft like" operational attributes required for a cost-effective SSTO system. Minimum key demonstrations include operability (e.g., increased thermal protection system (TPS) (i.e., a protection system on areas of the spaceplane subject to temperature extremes) robustness, weather, etc.), reusability, affordability, and safe abort; and

- verify full-scale systems operability and performance in "real world" environments.

2.1.2 Key Technology Requirements

Successful development of a fully reusable SSTO vehicle or spaceplane depends on achieving more maturity for and demonstrating the following key technologies:

- reusable cryogenic tank system, including the tank(s) for LOX and LH_2, cryogenic insulation, and integrated TPS;

- composite primary spaceplane structures with integrated TPS for both low and high temperatures;

- long life and low maintenance TPS;

- relative merits of existing propulsion systems and preferred propulsion system for meeting reuse, cost, and operations requirements of X-33 and RLV configurations;

- spaceplane health monitoring to facilitate inflight systems monitoring and postflight failure identification; and

- autonomous flight control of checkout, takeoff, ascent, flight, reentry, and landing for an uncrewed, remotely piloted spaceplane.

2.1.3 Specific Flight Test Objectives

The Advanced Technology Demonstration test flights will be designed to demonstrate the following:

- interaction of engines, airframe, and launch pad at takeoff;
- safe return to the takeoff site, in the event of an abort;
- automated landing at a designated point on the runway;
- the capability to achieve low operational cost; and
- "aircraft-like" operations.

2.1.4 Schedule

The X-33 Program schedule is shown in Figure 2.1-1. The schedule is divided into three phases. Phase I began in January 1995 and will continue through June 1996. X-33 Concept Definitions and Designs and this EA were prepared during this phase. Phase II, the X-33 Development/ Operations Phase, is planned to be initiated in July 1996, following execution of a Cooperative Agreement between NASA and the Industry Partner selected as a result of evaluation of proposals submitted in response to CAN 8-3. Operational RLV development will take place in Phase III. Phase III will begin in the year 2000, with emphasis on commercial development of an SSTO spaceplane.

2.2 Program Description

Due to budget and schedule requirements set forth by NASA in CAN 8-3, maximum use of existing facilities with minimum modifications or additions to existing facilities is anticipated. Many of the activities described below will be conducted in temporary, mobile facilities such as trailers and with potentially transportable takeoff support equipment. Basic elements of the X-33

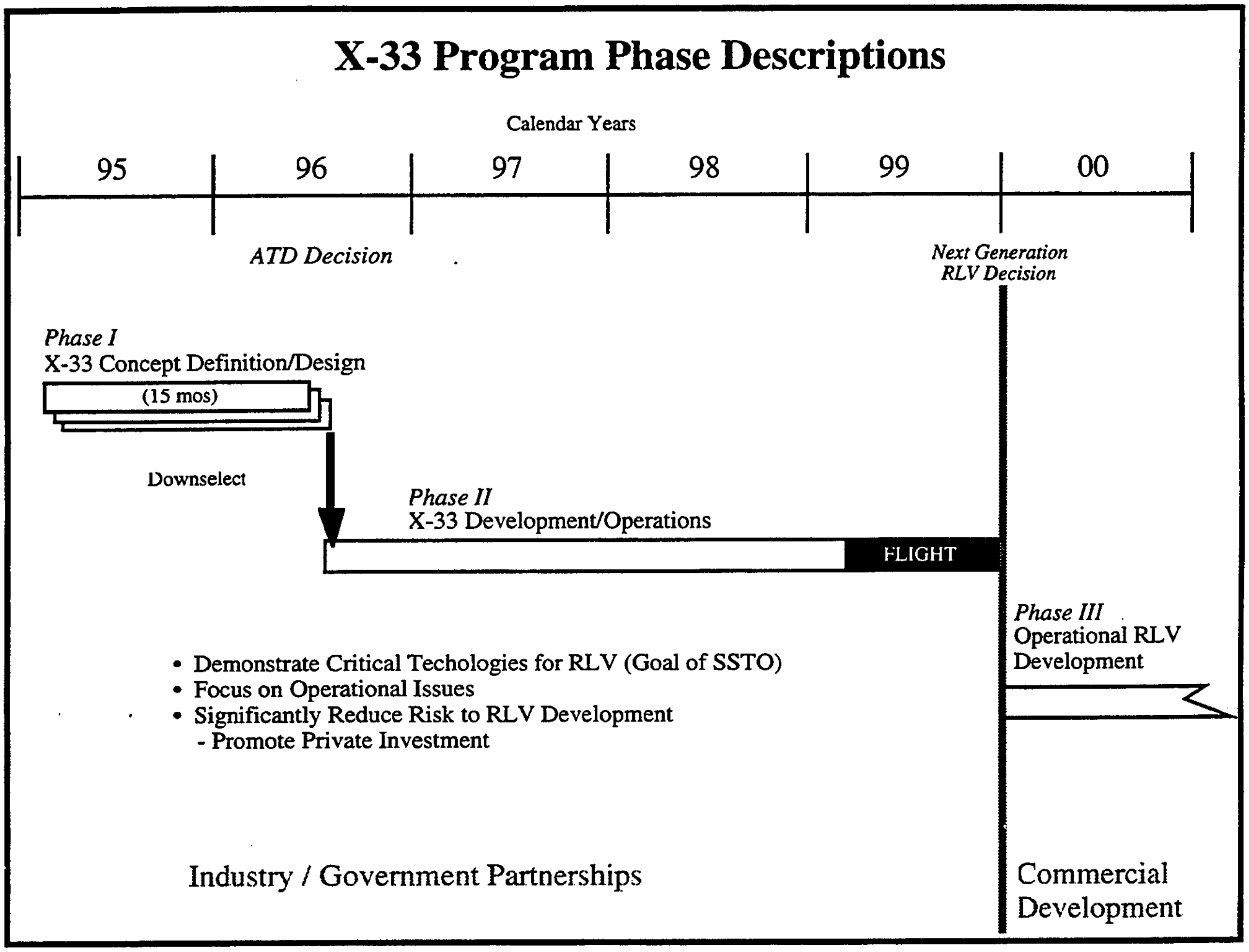

Figure 2.1-1. X-33 Program Phase Descriptions

Advanced Technology Demonstrator Program are shown in Figure 2.2-1 with potential major support installations shown in Figure 2.2-2.

2.2.1 Government Elements

Several major elements of the program are anticipated to be performed at Government installations as requested and negotiated by the selected Phase II Industry Partner. These activities may include research and development (R&D) of such key technologies as:

- Reusable cryogenic tank system
- Composite primary spaceplane structures
- Improved thermal protection systems
- Improved spaceplane health monitoring systems
- Autonomous flight control
- Aerodynamic and aerothermodynamic characterization
- Rocket propulsion
- Specialized computer modeling and simulations

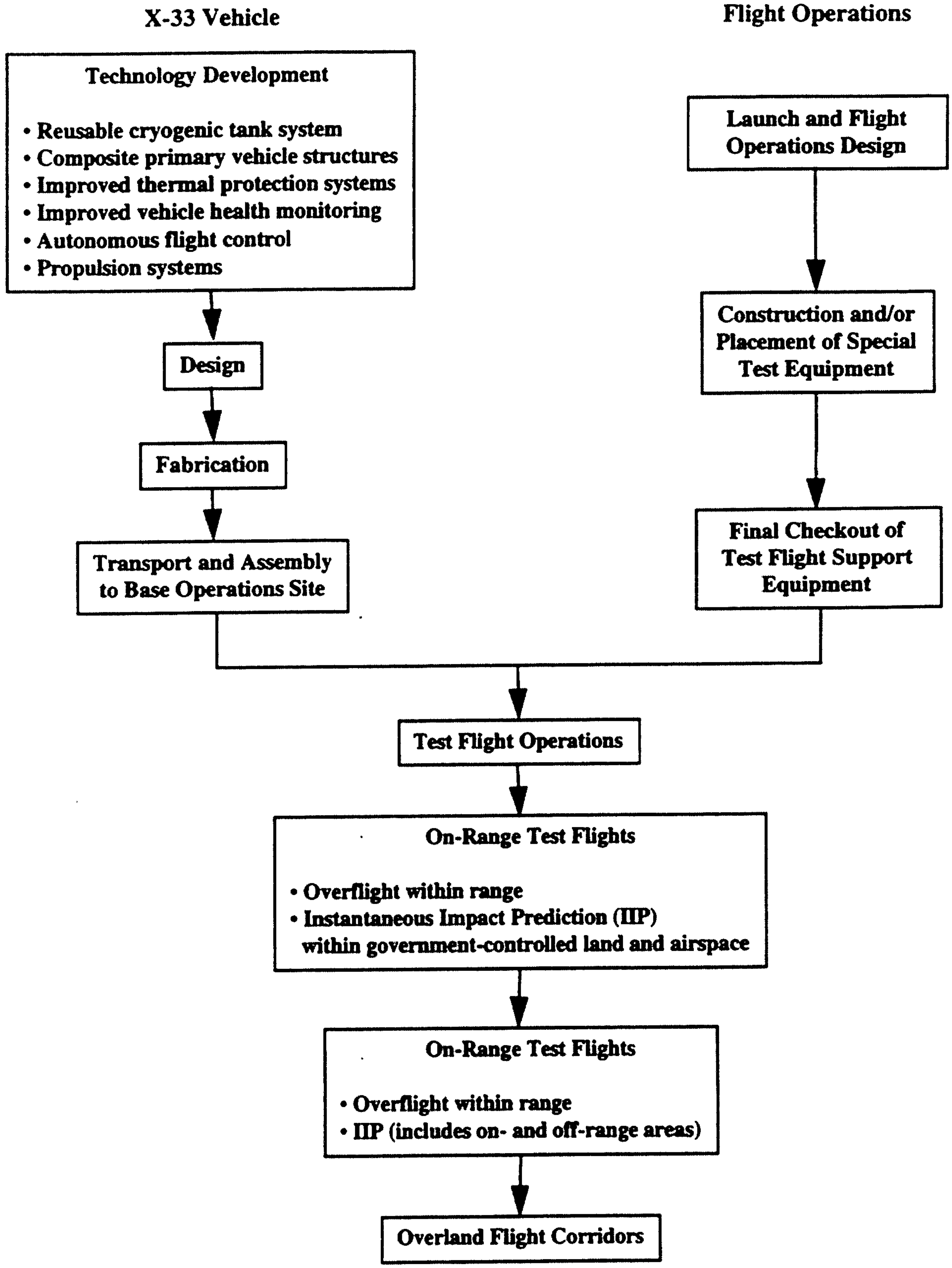

Figure 2.2-1. Elements of the X-33 Advanced Technology Demonstrator Program